



## ***Landslides***

### **Profiling Hazard Event**

**Requirement §201.4(c)(2)(i):** *[The State risk assessment **shall** include an overview of the] location of all natural hazards that can affect the State, including information on previous occurrences of hazard events, as well as the probability of future hazard events, using maps where appropriate ... .*

Landslides are a “down slope movement of a mass of rock, earth, or debris”. Landslides, often referred to as mass wasting or slope failures, are one of the most common natural disasters. (Cruden 36). Slope failures can vary considerably in shape, rate of movement, extent, and impact on surrounding areas. Slope failures are classified by they’re type of movement and type of material. The types of movement are classified as falls, slides, topples, and flows. “The types of material include rock, debris (coarse grained soil) and earth (fine grained soil)” (Eldredge 17). “Types of slope failures then are identified as rock falls, rock slides, debris flows, debris slides, and so on” (Eldredge 17). Slope failures occur because of either an increase in the driving forces (weight of slope and slope gradient) or a decrease in the resisting forces (friction, or the strength of the material making up a slope). “Geology (rock type and structure), topography (slope gradient), water content, vegetative cover, and slope aspect are important factors of slope stability” (Eldredge 18).

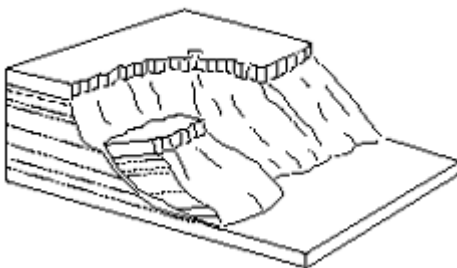
**Figure I-24 Three Common Types of Landslides in Utah**

#### **Debris Flow**

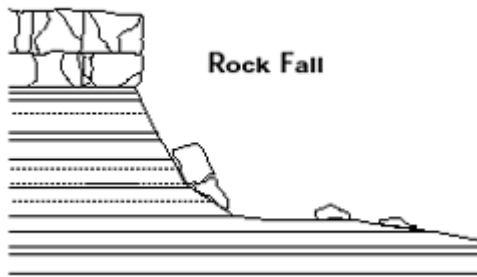


Debris flows consist of sediment-water mixtures that flow down a streambed or hillside, commonly depositing sediment at canyon mouths in fan like deposits know as alluvial fans.

#### **Slide**



Slides are down slope movements of soil or rock on slopes.



Rock falls consist of rock(s) falling from a cliff or cut slope and are very common in the canyon country of southern Utah.

### **Conditions That Make Slopes More Susceptible to Landslides**

- Discontinuities: faults, joints, bedding surfaces.
- Massive materials over soft materials.
- Orientations of dip slope: bedding planes that dip out of slope.
- Loose structure and roundness.
- Adding weight to the head of a slide such as: rain, snow, landslides, mine waste piles, buildings, leaks from pipes, sewers, and canals, construction materials fill materials.
- Ground shaking: earthquakes or vibrations.
- Increase in lateral spread caused by mechanical weathering.
- Removal of lateral support.
- Human activities: cut and fill practices, quarries, mine pits, road cuts, lowering of reservoirs.
- Removing underlying support: under cutting of banks in a river.
- Increase in pore water pressure: snow melt, rain, and irrigation.
- Loss of cohesion.
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### **Landslide History**

Nationwide, estimated losses from damaging landslides equal \$3.5 billion annually (USGS, 2005). In Utah, documented losses from damaging landslides in 2001 exceeded \$3 million, including the costs to repair and stabilize hillsides along state and federal highway (Ashland, 2003). Total landslide dollar losses are hard to determine for past events because a standard for documenting them do not exist. Several state and local agencies track landslide losses with inconsistent formats often resulting in several different totals for a single event. The recurrent or ongoing movement at very slow rates, of some slides, results in widespread, but typically limited damage. This movement, cumulatively over several years, causes damage. Francis Ashland, of the Utah Geologic Survey discusses landslide damages in Utah as well as the difficulties of accruing accurate post movement loss numbers. His work “The Feasibility of Collecting Accurate Landslide-Loss Data in Utah, Open File Report 410” is found in appendix K of this plan.

### **Thistle Slide:**

In 1983, the town of Thistle was destroyed by floodwaters when the Thistle landslide created a natural dam and subsequent reservoir blocking roads and rail line. The Marysville branch line, of the railroad was never reopened, leaving a large area of central Utah without rail service. Thistle resulted in Utah's first presidential disaster declaration

and became the most costly landslide in United States history. Three reports have been issued estimating the cost of the landslide between \$200 million and \$337 million dollars.

#### **Heather Drive Landslide:**

In 2001 this landslide destroyed three houses and forced the relocation of three others. Total dollar losses for this event have been estimated various sources between \$519,800 and \$1,092,000.

#### **Santaquin Mollie Fire Debris Flow:**

In August of 2001, the 8,000+ acre Mollie Fire burned an area of the Wasatch Range known as Dry Mountain above the city of Santaquin. The bench development area of Santaquin City is located not more than 50 yards from the edge of the fire perimeter on an alluvial fan. The Mollie wildfire, caused watershed damaged elevated the debris flow risk. At approximately 6:45 p.m. on Thursday, September 12, 2002, after nearly a week of intense thunderstorms, the charred earth of the ironically named Dry Mountain produced 10 debris flows. These flows did major damage to several houses and resulted in significant clean up costs.

#### **Buckley Draw—Springville Fire:**

The Springville fire started on June 30, 2002 at 7:19 p.m. and burned a total of 2,207 acres above dozens of homes. This burned area heightened the debris flow risk to those homes on the alluvial fans below. At the April 29, 2003 neighborhood meeting, the debris flows in Santaquin were contrasted with the conditions at the Buckley Draw. Plans for trench construction were discussed. A flag notification system and evacuation plan was put in place. A web link with updated hazard information, a phone ‘hot line’ with an updated message, and a notification procedure alerting the Neighborhood Chair of any changes in the hazard level were implemented. A practice evacuation drill was held on Saturday, May 10, 2003.

The 1,500 feet long trench/deflection dike was completed on July 28, 2003, by Provo City in conjunction with the NRCS and their Emergency Watershed Protection program. At approximately 3:00 a.m. on September 10, 2003, four separate debris flows were triggered. The newly finished trench routed the second largest flow. The trench finished “in a nick of time” worked as designed preventing property loss and potentially life loss. It is difficult to predict total amount of damage prevented by the trench, but at a minimum the deflection dike prevented damage equal to its construction cost. The spreader fences in the debris runout field distributed the runoff materials and completely contained this debris flow.

#### **Kanab Creek Landslide**

On March 12, 2005 at approximately 5:30 p.m., a 100 ft. long by 60 ft. high vertical stream-cut along Kanab Creek failed. This rock fall occurred within the city limits of Kanab, killing one boy and partially burying two children. This earth-fall-type landslide was most likely the result of long-term gravitational effects on over-steepened, unconsolidated material in the arroyo walls. (Lund, 2005)

### **Provo Rock Fall**

On May 12, 2005 at 5:00 p.m., a rock fall destroyed a guest house located in Provo. No fatalities resulted from the rock fall. The rock measured 7 x 5.1 x 4.5 feet and weighed approximately 13 tons. The rock fall is believed to have resulted from a series of significant storms that passed through the Provo area between May 10-12, in which approximately 3.7 inches of mixed rain and snow fell on the area. It was raining at the time of the rock fall (Giraud, 2005).

## ***Assessing Vulnerability by Jurisdiction***

**Requirement §201.4(c)(2)(ii):** *[The State risk assessment shall include an] overview and analysis of the State's vulnerability to the hazards described in this paragraph (c)(2), based on estimates provided in local risk assessments as well as the State risk assessment. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events. State owned critical or operated facilities located in the identified hazard areas shall also be addressed ... .*

**Requirement §201.4(d):** *Plan must be reviewed and revised to reflect changes in development...*

According to the USGS, landslides are a widespread geologic hazard that can occur in all 50 states. On average, landslides cause \$1-2 billion annually in damages and claim 25 lives per year. Urban development in and along hillside areas increase the number of people threatened by landslide events each year (USGS, 2007). Many factors contribute to overall landslide vulnerability; including local weather, soil moisture, duration and intensity of precipitation, wildfire history, and development pressure. Typically, landslides result from other natural disasters such as earthquakes, volcanoes, wildfires, and floods (USGS, 2007). Table I-22 illustrates how many square miles per county are in high or moderate landslide susceptible areas. Data for assessing landslide vulnerability was provided by the Utah Geological Survey.

**Table I-22 Area of square miles per county with high or moderate landslide risk**

<b>County</b>	<b>Areas within High or Moderate Landslide Susceptibility Areas (square miles)</b>
Beaver	625.6
Box Elder	1010.8
Cache	563.5
Carbon	818.4
Daggett	312.2
Davis	1515.7
Duchesne	104.6
Emery	128.02
Garfield	197.5
Grand	1537.9
Iron	758.7
Juab	803.6
Kane	1680.5
Millard	1187.8
Morgan	449.3
Piute	361.7
Rich	263.9
Salt Lake	321.63
San Juan	2512.3
Sanpete	783.6
Sevier	587.4
Summit	1035.8
Tooele	938.3
Uintah	1367.1
Utah	1076.7
Wasatch	717.91
Washington	1108
Wayne	785.4
Weber	261.8
<b>Total</b>	<b>23,815.66</b>

**Table I-23 Summary of Landslide Susceptibility per County by Hazard Category**

County Name	High Hazard (square miles)	Moderate Hazard (square miles)	Low Hazard (square miles)	Extremely Low Hazard (square miles)
Beaver	46.6	579	236.1	1365.4
Box Elder	33.3	977.5	417	3877
Cache	10.8	552.7	161.2	365.3
Carbon	7.1	811.3	219.4	407.3
Daggett	8.7	303.5	165.5	195.7
Davis	35.1	1480.6	562.8	1071
Duchesne	15.4	89.2	14.6	167.6
Emery	2.02	126	143.1	175.3
Garfield	3.7	193.8	223.5	1763.1
Grand	17.2	1520.7	547.9	1508.6
Iron	20.5	738.2	333	1906.5
Juab	15.2	788.4	211.4	1999.5
Kane	42	1638.5	672.9	1530.9
Millard	13.1	1174.7	396.9	4524.1
Morgan	25.7	423.6	92.3	46.7
Piute	65.9	295.8	121.6	211.7
Rich	1.2	262.7	227.3	449.4
Salt Lake	1.63	320	25	373.9
San Juan	102.6	2409.7	1287.8	3765.9
Sanpete	100.9	682.7	254.8	463.1
Sevier	149.7	437.7	317.2	458.5
Summit	80.1	955.7	417.9	348.1
Tooele	1.3	937	233.2	5396.4
Uintah	32.4	1334.7	906.2	2068.1
Utah	21.1	1055.6	195	591.3
Wasatch	9.51	708.4	247.3	160.1
Washington	28.1	1079.9	423.2	792.9
Wayne	48.7	736.7	323.6	1239.9
Weber	15	246.8	61.9	237.2

## Estimating Potential Losses by Jurisdiction

**Requirement §201.4(c)(2)(iii):** [The State risk assessment **shall** include an] overview and analysis of potential losses to the identified vulnerable structures, based on estimates provided in local risk assessments as well as the State risk assessment. The State **shall** estimate the potential dollar losses to State owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas.

**Requirement §201.4(d):** Plan must be reviewed and revised to reflect changes in development...

The Utah counties are ranked based on total area in square miles that are within high or extreme landslide susceptibility areas

1. San Juan	11. Tooele	21. Morgan
2. Kane	12. Carbon	22. Piute
3. Grand	13. Juab	23. Salt Lake
4. Duchesne	14. Wayne	24. Daggett
5. Uintah	15. Sanpete	25. Rich
6. Millard	16. Iron	26. Weber
7. Washington	17. Wasatch	27. Garfield
8. Utah	18. Beaver	28. Emery
9. Summit	19. Sevier	29. Davis
10. Box Elder	20. Cache	

### ***Assessing Vulnerability by State Facilities***

***Requirement §201.4(c)(2)(ii):*** *[The State risk assessment shall include an] overview and analysis of the State’s vulnerability to the hazards described in this paragraph (c)(2), based on estimates provided in local risk assessments as well as the State risk assessment. The State shall describe vulnerability in terms of the jurisdictions most threatened by the identified hazards, and most vulnerable to damage and loss associated with hazard events. State owned critical or operated facilities located in the identified hazard areas shall also be addressed ... .*

***Requirement §201.4(d):*** *Plan must be reviewed and revised to reflect changes in development...*

State facilities data updated in April 2006 was provided by Utah’s AGRC. The data presented in this shape file was compiled with the help of several state agencies and entities. The state-owned facilities shape file was overlaid on top of the 2006 Utah Geological Survey landslide susceptibility shape file. Using ArcView 9.2, landslide susceptibility areas were clipped from a county shape files for each Utah county. The “select by location” option was then utilized in order to determine how many vulnerable state facility structures exist per county.

**Table I- 24 Total Number of State Owned Facilities in Landslide Susceptibility Areas**

<b>County</b>	<b>Total Vulnerable Structures</b>
Beaver	1
Box Elder	1
Cache	66
Carbon	4
Daggett	0
Davis	2
Duchesne	0
Emery	6
Garfield	4
Grand	1
Iron	5
Juab	1
Kane	8
Millard	3
Morgan	23
Piute	0
Rich	4
Salt Lake	52
San Juan	4
Sanpete	9
Sevier	6
Summit	24
Tooele	2
Uintah	0
Utah	9
Wasatch	7
Washington	21
Wayne	5
Weber	20
<b>Total</b>	<b>288</b>



## Estimating Potential Losses by State Facilities

**Requirement §201.4(c)(2)(iii):** [The State risk assessment **shall** include an] overview and analysis of potential losses to the identified vulnerable structures, based on estimates provided in local risk assessments as well as the State risk assessment. The State **shall** estimate the potential dollar losses to State owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas.

**Requirement §201.4(d):** Plan must be reviewed and revised to reflect changes in development...

Approximate current values for state owned facilities were provided by the AGRC. Current values of the state owned facilities were updated in 2006. ArcView 9.2 was used to determine which state-owned facilities are within high or moderate landslide susceptibility areas. The current values of those facilities within high or moderate landslide susceptibility areas were then summed in order to determine the total estimated current value of at-risk facilities for each county.

**Table I- 25 Total Insured Value of State Owned Facilities in Landslide Susceptibility Areas**

County	Total Vulnerable Structures	Estimated Current Value
Beaver	1	\$0.00
Box Elder	1	\$225,000.00
Cache	66	\$193,213,633.00
Carbon	4	\$95,311.00
Daggett	0	\$0.00
Davis	2	\$7,000.00
Duchesne	0	\$0.00
Emery	6	\$658,931.00
Garfield	4	\$182,988.00
Grand	1	\$18,560.00
Iron	5	\$861,272.00
Juab	1	\$0.00
Kane	8	\$686,140.00
Millard	3	\$0.00
Morgan	23	\$741,560.00
Piute	0	\$0.00
Rich	4	\$187,516.00
Salt Lake	52	\$346,571,236.00
San Juan	4	\$350,780.00
Sanpete	9	\$852,318.00
Sevier	6	\$841,962.00
Summit	24	\$5,838,035.00
Tooele	2	\$0.00
Uintah	0	\$0.00
Utah	9	\$2,515,570.00
Wasatch	7	\$2,652,814.00
Washington	21	\$16,597,838.00
Wayne	5	\$430,980.00
Weber	20	\$27,704,268.00
<b>Total</b>	<b>288</b>	<b>\$601,233,712.00</b>

The number of people per three arc-seconds (approximately 90m x 70 m) within either high hazard or moderate hazard landslide susceptible areas was calculated to estimate the possible number of people that could be affected by landslides. The “select by location” feature found in the ArcView 9.2 software package was used to determine how many people are located within a high or moderate hazards zones. The UGS provided the landslide shape file. This shape file contains information about the location of landslide hazard areas and categories ranging from minimal risk to high risk to express how susceptible areas locations are to a landslide. LandScan 2005 provided population location data for daytime and nighttime hours. The Landscan data set was derived by the Oak Ridge National Laboratory utilizing a combination of information such as 2000 census data, proximity of population to roads, slopes, land cover, night-time lights, and other information that is then apportioned to each three second arc-second grid areas. An arc-second is a measure of latitude and longitude used by geographers that equates to approximately 90 meters by 70 meters in area. It is important to note that when working with population density data points, a 90m X 70m resolution is at a finer scale than census block data.

**Table I-26 Total Daytime Population per County within High or Moderate Landslide Susceptibility Areas**

County	Total Daytime Population
Beaver	130
Box Elder	1,051
Cache	6,873
Carbon	1,101
Daggett	263
Davis	390
Duchesne	9,348
Emery	305
Garfield	652
Grand	840
Iron	509
Juab	147
Kane	570
Millard	225
Morgan	803
Piute	53
Rich	27
Salt Lake	23,573
San Juan	782
Sanpete	562
Sevier	942
Summit	5,817
Tooele	405
Uintah	412
Utah	12,943
Wasatch	793
Washington	7,844
Wayne	66
Weber	9,220

**I-27 Total Night-time Population per County within High or Moderate Landslide Susceptibility Areas**

<b>County</b>	<b>Total Night-time Population within High or Moderate Landslide Susceptibility Areas</b>
Beaver	90
Box Elder	1,742
Cache	5,745
Carbon	887
Daggett	86
Davis	390
Duchesne	20,454
Emery	217
Garfield	39
Grand	671
Iron	633
Juab	338
Kane	444
Millard	19
Morgan	1,590
Piute	22
Rich	35
Salt Lake	24,443
San Juan	304
Sanpete	291
Sevier	230
Summit	7,502
Tooele	329
Uintah	427
Utah	12,252
Wasatch	719
Washington	6,226
Wayne	75
Weber	16,421